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UNAMAP - User's Network for the Applied Modeling of Air Pollution

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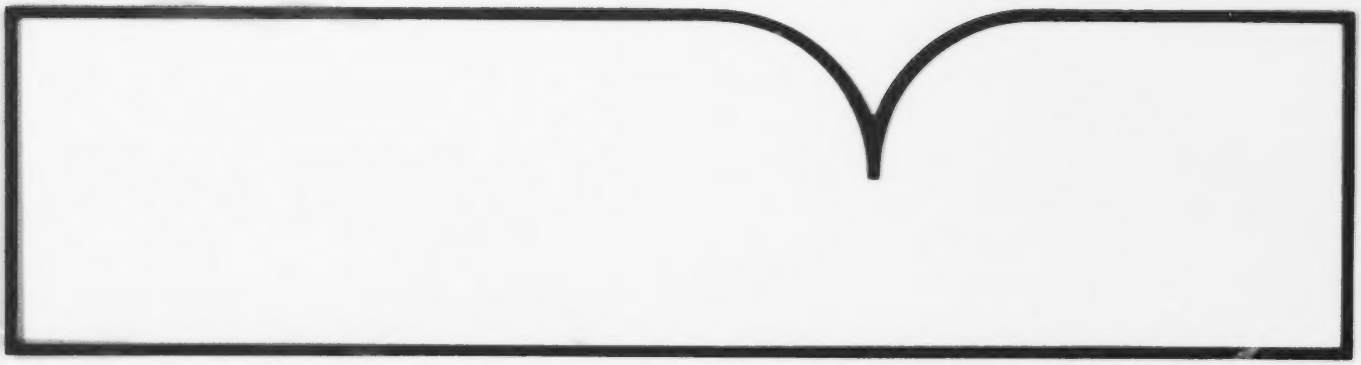

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UNAMAP--USER'S NETWORK FOR THE APPLIED MODELING OF AIR POLLUTION

By

Thomas E. Pierce* and D. Bruce Turner*
Atmospheric Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

EPA Project Officer
D. Bruce Turner

*On assignment from the National Oceanic and Atmospheric Administration

ATMOSPHERIC SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

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16. ABSTRACT

The Users' Network for the Applied Modeling of Air Pollution (UNAMAP) was initiated by EPA in 1973. It was conceived as a means of distributing air pollution models to a variety of organizations around the country. Since 1973, UNAMAP has grown from 6 models to 23 models.

This report provides a brief description of the UNAMAP system. It also discusses the impact that changes in National Weather Service meteorological data will have on air pollution models.

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UNAMAP - Users Network for the Applied Modeling of Air Pollution

Thomas E. Pierce* and D. Bruce Turner*

Atmospheric Sciences Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

1. INTRODUCTION

During the past 30 years, air pollution modeling has played an increasingly important role in environmental protection. In the United States, significant advances in air pollution modeling began with the passage of Public Law 159 in 1955. This law called for the development of forecasting techniques and models for predicting air pollution levels. Later in the 1950s and 1960s, advances in air pollution modeling resulted from the growth and subsequent regulation of the nuclear power industry. The growth of air pollution modeling, however, mushroomed with the passage of the Clear Air Act in 1970. With passage of this act, Congress created the Environmental Protection Agency which was given the task of developing air pollution models to ensure that various types of industrial sources complied with air quality standards.

To meet the demand for standard air pollution models, EPA in 1973 initiated the Users Network for the Applied Modeling of Air Pollution (UNAMAP). UNAMAP was conceived as a way of distributing EPA-sponsored air pollution models to private and public organizations around the country. Users were given access to UNAMAP through one of two means. EPA users could execute the models through the EPA central computer. Magnetic tapes containing FORTRAN source code were made available to non-EPA users through the National Technical Information Service (NTIS).

From 1973 to 1986, UNAMAP grew from 6 models to 23 models. The latest version of UNAMAP, Version 6, was released in September 1986. Since 1973, over 300 different groups have purchased UNAMAP through NTIS. Since September 1986, over 50 persons have accessed UNAMAP through EPA's computer; unfortunately figures are not available for earlier versions of UNAMAP. However, an indication of the popularity of UNAMAP is the existence of at least four consulting firms that actively market UNAMAP programs for personal computer (PC) and IBM mainframe computer application. The number of clients who have obtained models from these firms is unknown, but including the EPA and NTIS users it is estimated that several hundred organizations now make use of the UNAMAP system.

In the remainder of this paper, a brief description will be provided of the models and programs available on UNAMAP. In addition, the future of air pollution modeling will be examined for UNAMAP programs and for other more specialized and complicated models.

* On assignment from the National Oceanic and Atmospheric Administration.

2. DESCRIPTION OF UNAMAP MODELS

The most common means of obtaining UNAMAP is through purchase of a computer tape from NTIS. The current version of UNAMAP (Version 6) consists of a tape containing 68 files of FORTRAN source codes for the models, meteorological processors, test input data, and print files showing the results for the test cases. The models can be divided into regulatory models and newer research-oriented models.

The components of an air pollution model are given in Figure 1. Operation of a air pollution model usually begins with the input of emissions and meteorological data. The user also specifies where concentrations are to be estimated and over what averaging periods. Then using mathematical equations that simulate diffusion processes in the atmosphere, pollutant concentrations are calculated. It is important to note that these models primarily rely on historical or climatic data. In the case of a proposed pollution source, projected instead of actual emissions are used. The estimated concentrations are used to determine whether a proposed source is permitted to operate and if so what pollution control measures should be employed.

A sample description of some of the UNAMAP programs (Turner and Bender, 1986) is given below.

Buoyant Line and Point Source Model (BLP)

BLP is a Gaussian plume dispersion model designed to handle unique modeling problems associated with aluminum reduction plants, and other industrial sources where plume rise and downwash effects from stationary line sources are important. Typically, BLP predicts hourly concentrations from pollutants such as sulfur dioxide and particulates.

Climatological Dispersion Model (CDM)

CDM (Version 2.0) determines long-term (seasonal or annual) quasi-stable pollutant concentrations in rural or urban settings using average emission rates from point and area sources and a joint frequency distribution of wind direction, wind speed, and atmospheric stability. The Gaussian plume hypothesis forms the basis for the calculations. Contributions are calculated assuming the narrow plume hypothesis, and involve an upwind integration over the area sources. Computations can be made for up to 200 point sources and 2500 area sources at an unlimited number of receptor locations. The number of point and area sources can be easily modified within the code. CDM-2.0 includes the following enhancements over an earlier version of the model: 16 or 36 wind-direction sectors; initial plume dispersion; buoyancy induced

dispersion; stack-tip downwash; and gradual (transitional) plume rise. The user has a choice of seven dispersion parameter schemes. Optional output includes point and area concentration roses and histograms of pollutant concentrations by stability class.

Industrial Source Complex Short-Term Model (ISCST)

The ISCST model is a steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex. This model can account for settling and dry deposition of particulates, downwash, area, line and volume sources, plume rise as a function of downwind distance, separation of point sources, and limited terrain adjustment. Average concentrations or total deposition may be calculated for 1 to 24 hour time periods. A seasonal or annual concentration may also be calculated from the total number of modeled hours.

Integrated Puff Dispersion Model (INPUFF)

INPUFF 2.1 is a Gaussian integrated puff model with a wide range of application. The implied modeling scale is from tens of meters to tens of kilometers. The model is capable of addressing the accidental release of a substance over several minutes, or of modeling the more typical continuous plume from a stack. Requests to the Meteorology Divsion of EPA for assistance in modeling the air quality downwind of incineration ships prompted the development of INPUFF. INPUFF is, therefore, capable of simulating moving point sources as well as stationary sources.

Computations by INPUFF can be made for multiple point sources at up to 100 receptor locations. In practice, however, the number of receptor locations should be kept to a minumum to avoid excessive computer time. INPUFF is primarily designed to model a single event which may include one meteorological transition period, such as going from afternoon to evening. Up to 144 separate meteorological periods of the same length may be used to characterize the meteorology during the event; this provides a time resolution that ranges from minutes to an hour. The user has the option of specifying the wind field for each meteorological period at up to 100 grid locations or allowing the model to assume a homogeneous wind field.

Photochemical Box Model (PBM)

The PBM is a simple stationary single-cell model with a variable height lid designed to provide volume-integrated hour averages of ozone and other photochemical smog pollutants of interest for an urban area for a single day of simulation. The PBM is most appropriate for application in air stagnation conditions with light and variable winds. Horizontal dimensions of the box are typically of the order of 10-50 km; the vertical dimension may vary between 0.1 and 2 km. Chemical reactions are simulated using a 63-step kinetic mechanism that includes diurnal variation of photolytic rate constants. The depth of the mixed layer, or depth of the PBM domain, also follows a diurnal pattern; it can be optionally specified as following a non-linear growth curve. The PBM assumes that emission sources are homogeneously distributed across the surface face of the box volume and that the volume is well mixed at all times. Atmospheric diffusion and wind shear are neglected.

The user must provide the model with initial species concentrations, hourly inputs of wind speed, wind direction, source emission fluxes of carbon monoxide, oxides of nitrogen, total hydrocarons, hydrocarbon reactivity classes, and boundary species concentrations. Values of measured solar radiation and mixed layer depth may be specified at sub-hourly intervals throughout a simulation. The services of a qualified dispersion meteorologist, a chemist, and a computer programmer may be necessary to implement and apply PBM and to interpret the results.

Plume Visibility Model (PLUVUE)

PLUVUE-2 is designed to predict the transport, atmospheric diffusion, chemical conversion, optical effects, and surface deposition of point-source emissions. PLUVUE-2 performs plume optics calculations in two modes. In the plume-based mode, the visual effects are calculated for a variety of lines of sight and observer locations relative to the plume parcel. In the observer-based mode, the observer position is fixed and visual effects are calculated for the specific geometry defined by the positions of the observer, plume, and sun.

Meteorological Processor - RAMMET

RAMMET processes hourly surface meteorological observations (format TD-1440 from the National Climatic Data Center) to determine a Pasquill stability class for each hour. It also interpolates between twice-daily mixing height data (NCDC's format TD-9689) to obtain a mixing height value for each hour. An output tape or disk file is produced that contains a record for each day. Normal use is to process a calendar year of hourly data. The output file may be used as meteorological input to models such as RAM, CRSTER, MPTER, and ISCST.

Meteorological Processor for Diffusion (MPDA-1)

MPDA-1 is the first version of an advanced meteorological processor for organizing available meteorological data into a format accessible for diffusion analysis. MPDA-1 provides methods for using three types of data: NWS twice-daily rawinsonde reports, NWS hourly surface observations, and user-supplied onsite data. To determine surface scaling parameters, MPDA-1 is structured in accordance with current concepts of the idealized states of the planetary boundary layer. Profiles of wind velocity, temperature, and standard deviations of vertical and horizontal wind velocity fluctuations at user-specified heights are estimated. Output from MPDA-1 was formatted to accomodate the TUPOS Gaussian-plume model which uses wind fluctuation data to characterize the diffusion parameters. Future versions will provide additional output formats to accommodate other commonly-used diffusion models.

3. FUTURE OF MODELING

The growth of air pollution modeling has been characterized by the evolution of two different branches of modeling. After 15 years, UNAMAP models have matured and now are in common use. Meanwhile regional-scale and chemically-reactive models are just reaching adolescence, but are being assigned an increasing amount of responsibility.

These two groups of models can be distinguished by the number of organizations who use the models and by the amount and type of data needed to run the models. Many of the UNAMAP models primarily are needed for assessing single source impact within about 15 km of a source and therefore need data from only one meteorological station. Because of their simplicity, these models are used quite frequently by industry, consultants, and state and local air pollution authorities. On the other hand, regional scale models require large amounts of data on meteorology and emissions and a large amount of computer space and time. The input requirements for chemically-reactive models are even more extensive since they require background species and initial conditions.

Recognizing that regional and chemically-reactive models are needed to address national problems (such as ozone and acid deposition), and the necessary data, computer resources, and expertise for operating these models do not readily exist, the Meteorology Division of EPA is organizing a center for the advanced analysis of atmospheric pollution. The center will serve the needs for various groups within EPA and possibly other federal agencies. The center will also serve as the focal point for incorporating advances in atmospheric research into the modeling framework. As experience is gained with the center, it may show a need to develop a similar non-government center to serve industry and environmental groups.

The future of UNAMAP is being shaped by an increased reliance on personal computers and the modernization of the National Weather Service. The increased reliance of personal computers (PCs) is reflected in the number of private firms which are offering services to distribute PC versions of the UNAMAP models. Many organizations now depend on PCs, which are computationally equivalent to the mainframe computers of a decade ago. UNAMAP models are for the most part easily adapted to the PC and can usually run in less than an hour. More importantly, the PC offers an attractive economic alternative to mainframe computer charges. After a number of simulations, the costs for a PC can be justified because of savings in computer charges.

One problem hindering the application of UNAMAP models on a PC has been the need to access meteorological data bases. However, the National Climatic Data Center (Heim, 1987) now offers meteorological data bases in TD-1440 and TD-9689 formats on diskettes compatible with many PCs. Also, as the memory capacity of hard disk drives continues to increase, storage of large meteorological data bases will become less of a problem. Transfering data via phone lines is still relatively cumbersome, but it too is likely to improve as advances proceed in communications technology.

Recognizing the emergence of PCs in air pollution modeling, the Meteorology Divsion of EPA is beginning to develop computer programs on the PC (e.g., Petersen, 1986; Turner, 1986). It should be noted that it has always been the philosophy to make the UNAMAP programs as transportable as possible. ANSI-77 standard FORTRAN is used for coding, and system dependent coding practices are avoided whenever possible. Therefore, adaptation of existing programs to the PC has been relatively straightforward as long as an ANSI standard FORTRAN compiler has been available. Another recent development has been the implementation of a UNAMAP bulletin board. It is designed so that users may obtain information about UNAMAP by dialing in through a modem. However, the bulletin board probably will not be set up to transmit computer code because of the long connect times which would be required to transmit say a 2000 line FORTRAN code at 1200 bps. Persons desiring additional information about the bulletin board are advised to call Mr. Bill Petersen at (919) 541-1376 or FTS 629-1376.

Modernization activities in the NWS are also being keenly watched. The implementation of automated surface observing systems (ASOS), automated weather interactive processing system (AWIPS), next generation of radar (NEXRAD), and remote profilers will affect UNAMAP and the other more complicated air pollution models. The additional data generated with NEXRAD, especially surface rainfall patterns, have application for acid deposition models. ASOS is of interest because of changes in the measurements of visibility, cloud cover, and ceiling height. Cloud cover and ceiling height are particularly important in air pollution modeling because they are used in determining atmospheric stability. Unfortunately, ASOS is currently not equipped to estimate clouds above 14,000 feet. However, a cirrus deck can significantly influence surface heating and therefore estimates of stability class. Also of interest is the development of remote profilers which probably represents the future in upper-air measurement systems. Currently, the wind profiler begins sampling 700 m above the earth's surface. However, for boundary layer and air pollution models, measurements of winds and temperature in the lowest 1000 m of the atmosphere are essential. If the vertical limit of the profiler is lowered, its hourly measurements should significantly improve the capabilities of air pollution models. In terms of data dissemination, AWIPS is being watched because some future models may require the input of near-real-time and forecast data, especially for emergency response modeling. In addition, it is important to know how AWIPS will interact with the National Climatic Data Center (NCDC).

NCDC provides most meteorological data used with UNAMAP programs. Data currently being used include hourly surface observations (TD-1440), twice-daily mixing heights (TD-9689), twice-daily rawinsonde reports (TD-5600), and STAR frequency tabulations (TD-9773). Changes in these formats and the introduction of new formats are being coordinated with NCDC. The introduction of the new element formats (TD-3280 and TD-6200) will require fairly extensive modifications to existing UNAMAP software. However, many air pollution modelers are looking forward to the improved data that will be available from the new NWS instrument systems, such as NEXRAD and remote profilers.

In conclusion, air pollution modeling is in a rapid state of development. Complicated models such as those used for predicting acid deposition will need to adapt to the additional data provided with the new NWS instrumentation. In the near term, they will likely be operated by groups who have the expertise and computer resources to operate them efficiently and accurately. UNAMAP models, meanwhile, will be adapting to the growing popularity of desktop computers and the additional data to be collected by the National Weather Service (NWS).

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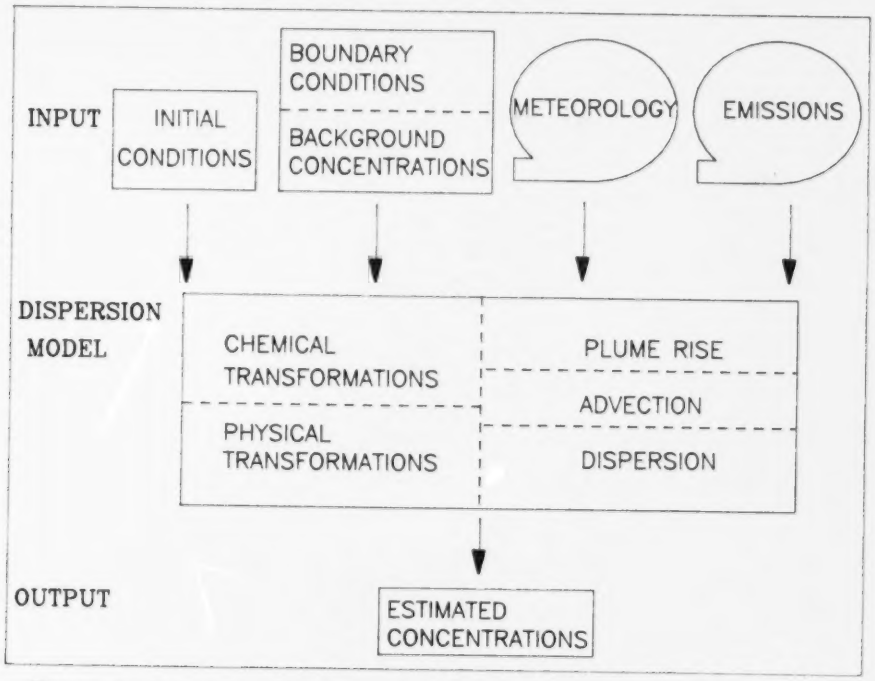

Figure 1. Components of an air pollution model.